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MEMORANDUM REPORT  
MC 4-26-1

UNITED STATES ARMY

# FRANKFORD ARSENAL

PYROTECHNIC DELAY DEVICES  
FOR  
LOW ENERGY DETONATING CORD SYSTEMS

by

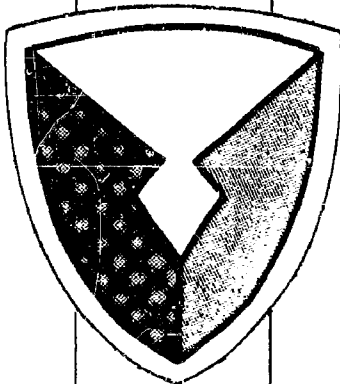
J. F. KOWALICK

OMS Code 4110.16.8500.1.20

April 1961

PHILADELPHIA, PA. 19137

REPORT MC 4-26-1



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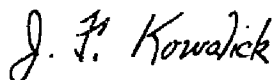
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MEMORANDUM REPORT M64-26-1

PYROTECHNIC DELAY DEVICES FOR  
LOW ENERGY DETONATING CORD SYSTEMS

OMS Code 4110.16.8500.1.2G

Prepared by



J. F. KOWALICK  
Chemical Engineer

Reviewed by



T. Q. CICCONE  
Chief  
Combustion and Detonation Section

Approved by



A. L. JAMIESON  
Deputy Director  
Pitman-Dunn Institute for Research

April 1964

FRANKFORD ARSENAL  
Research and Development Group  
Philadelphia, Pa.

## ABSTRACT

A study was initiated to survey the field of pyrotechnic delay devices as such devices pertain to systems where relatively low energy transfer is accomplished through detonating cord having a core of small amounts of high explosive.

Detonating fuse delays developed for use in the blasting industry incorporate powder trains of the sequence - high explosive, to deflagrating composition, to delay composition. Although such delays appear to be in common use, their delay times do not exceed approximately 300 milliseconds and their reliability has not been established.

Furthermore, a design problem may exist in scaling up the delay time to the order of several seconds. Functional descriptions of these delays are presented.

A method is presented for providing a complete seal between detonating cord and the delay device.

References cited, although not all-inclusive, are indicative of current and past interest in this subject.

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## INTRODUCTION

In earlier investigations, the adaptability of mild detonating fuse (MDF), a low energy detonating cord, to aircraft escape systems was demonstrated<sup>1\*</sup> and simple prototype escape systems with MDF as the energy transfer medium were tested.<sup>2</sup> In the prototype system, a Du Pont nominal 2-second delay element (Figure 1) was substituted for the M5 PAD delay cartridge and was attached to MDF by crimping. This element was light in weight (4.5 grams) and had a reported burning time of 2.0 seconds  $\pm$  10 percent.

It was concluded that such delay elements were readily adaptable to an MDF system but, like standard delays used in aircraft escape systems, they would require testing and standardization. A need still exists for a standardized delay of several seconds' duration for use in MDF lines in proposed aircraft escape systems.

## CLASSIFICATION OF DETONATING FUSE DELAYS

It is convenient to classify detonating fuse delays reported in publications and in letter patents into two categories: (1) those having a mechanical barrier between the detonating cord and the delay composition; and (2) those having a continuous explosive and/or propellant train between the detonating cord and the delay composition. The former category includes barriers that act as firing pins, thereby initiating a primary explosive by percussion in a delay unit.

### Percussion Barriers

A delay train which is initiated by percussion of a primer containing high explosive can be fabricated by modifying any number of existing delays to MDF-initiated percussion delays. Examples of such delays are the MK-13-0 (Figure 2), a 1.5-second delay element,<sup>3</sup> the MK-14-0, a 1.6-second delay,<sup>4</sup> and a host of delays described in the journal of the JANAF Fuse Committee.<sup>5</sup>

The train from primary explosive to delay composition in these delays invariably involves the use of baffles or porous media as "softening" agents. (Note baffling in Figure 2.) A description and sketch of the MK-10 Mod 0 delay element, suitable for direct percussion-ignition by detonating cord, is presented in Figure 3.

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\*See REFERENCES.



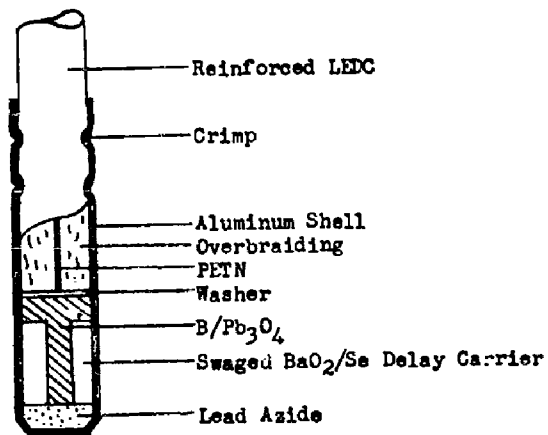


Figure 1. DuPont 2-second Delay

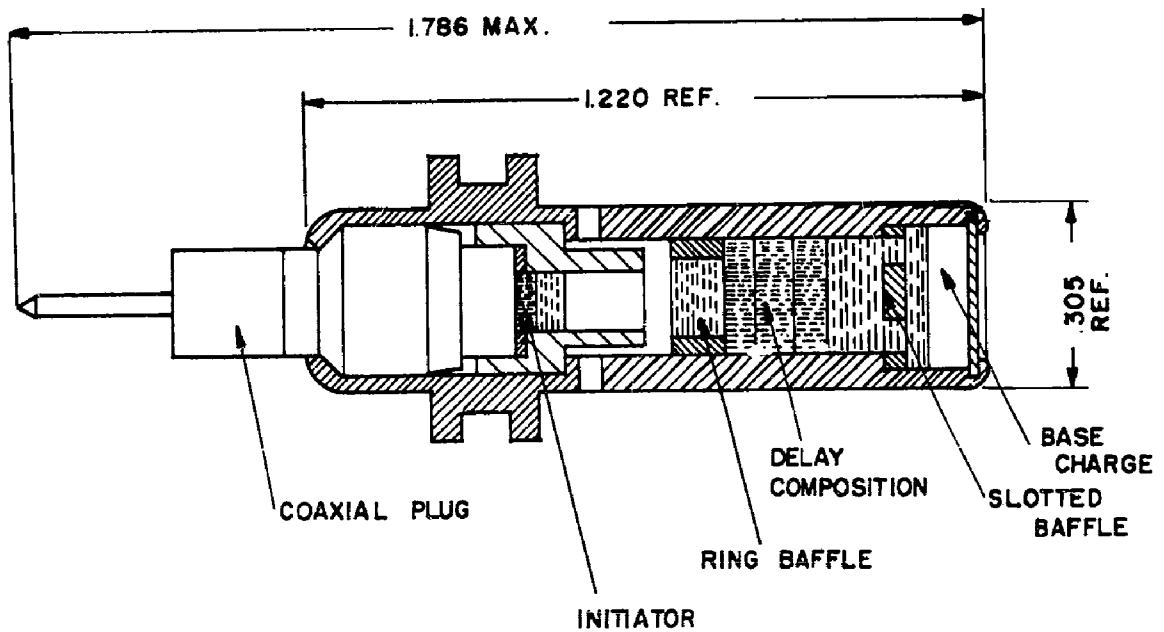
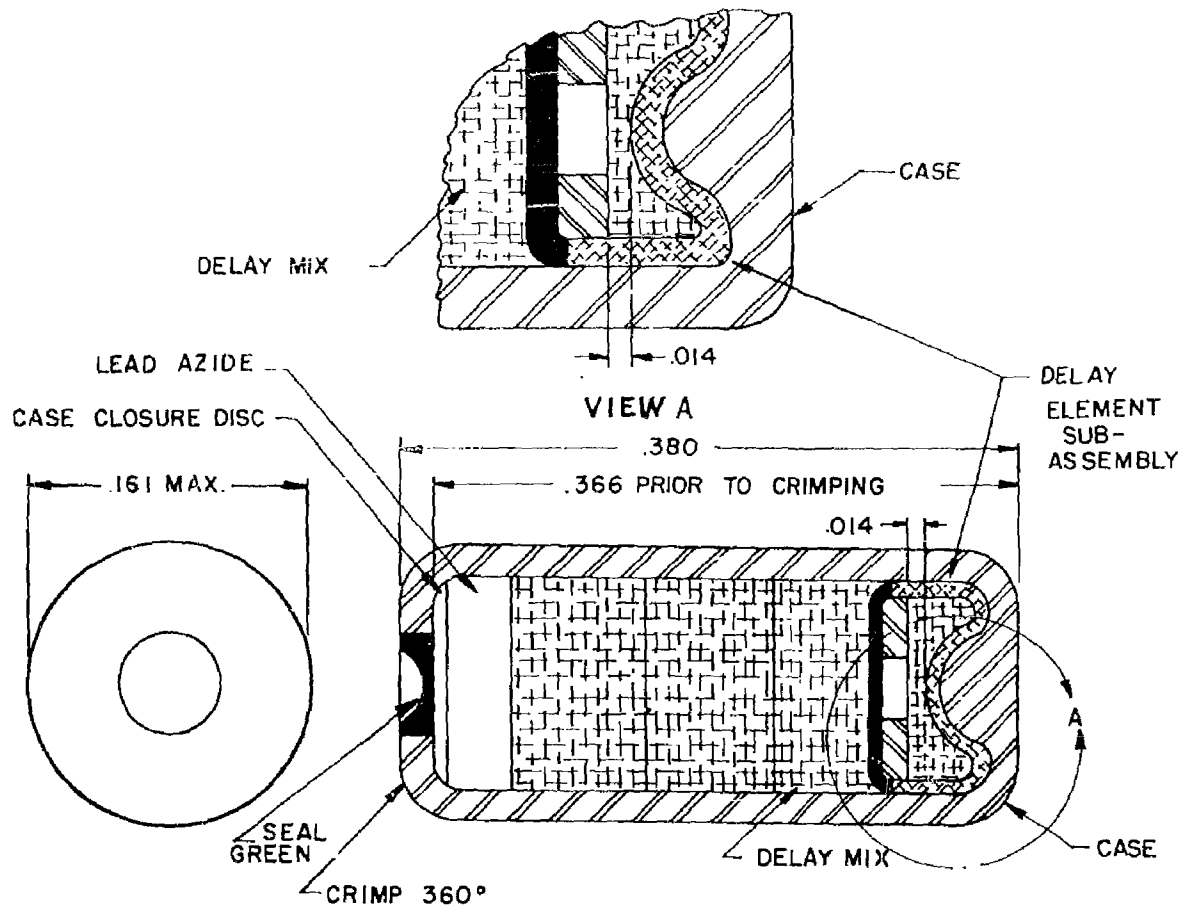


Figure 2. Actuator Delay, MK 13-0



This is a 600-microsecond delay which was designed for use in the MK 176 Fuze for the 2.75 in. Folding Fin Aircraft Rocket. In essence, the delay element subassembly depicted in drawing 652212 is a percussion primer. Firing of this delay is accomplished by driving a diaphragm in the fuze rotor against the end of the delay element. Driving force is derived from firing a stab primer (MK 125 Mod 1) upon fuze contact with the target.

Figure 3. Delay Element, MK 10, Mod 0

## Explosive-Propellant Train Delays

The design technology of pyrotechnic and explosive trains, although highly developed, is largely empirical. Therefore, in designing for a new application it is very helpful to consider past designs that have functioned with some degree of success. Although letter patents<sup>6,7,8,9,10,11</sup> describe a number of powder-train delay devices for use in detonating fuse lines, they are limited to delay intervals of from 20 to 300 milliseconds.\*

A typical design<sup>6</sup> (Figure 4) describes a delay which is symmetrical and can be used with PETN detonating cord. The detonating propagates from the detonating cord (fuse) to a primary explosive, such as lead azide, which is housed in a funneled lead cylinder. The inside wall along the funnel absorbs much of the shock, permitting a transfer to deflagration of a relatively gasless composition, such as boron/potassium nitrate or lead dioxide/silicon. This composition burns up to a baffle washer which prevents the delay composition from dispersing, yet allows it to ignite. The delay mixture was smokeless powder/ $\text{KClO}_4$ /lead sulfocyanate. It is claimed that this device functions in either direction, with a delay time range of 20 to 30 milliseconds. No reliability data are reported.

Another patent<sup>7</sup> suggests a method for incorporating a delay of several seconds into a detonating fuse line. Figure 5 shows the suggested sequence - from detonating fuse to blasting cap, to a transmission line (consisting of impregnated black powder in a woven fabric), to a delay composition (such as red lead/silicon/black powder/oxidizer), through a baffle to a blasting cap, and back to detonating fuse.

Patents 2,707,439,<sup>8</sup> "Short Interval Delay Blasting Device," and 2,841,476,<sup>9</sup> "Delay Blasting Device," are similar in scope to the device shown in Figure 4. A patent<sup>10</sup> by H. A. Lewis et al, "Blasting Explosive Device," cites examples of six blasting delays varying in operation time from three to 353 milliseconds. Four different designs are sketched, and a tabulation is presented showing delay times for variations in mechanical components and compositions.

A patent<sup>11</sup> by F. H. G. McCaffrey describes a nominal 50-millisecond delay device which would have a time deviation of 411 milliseconds from the mean value in greater than 99 percent of the cases.\*\*

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\*Title pages of patents described in this section are included in the Appendix.

\*\*Temperature of functioning is not indicated.

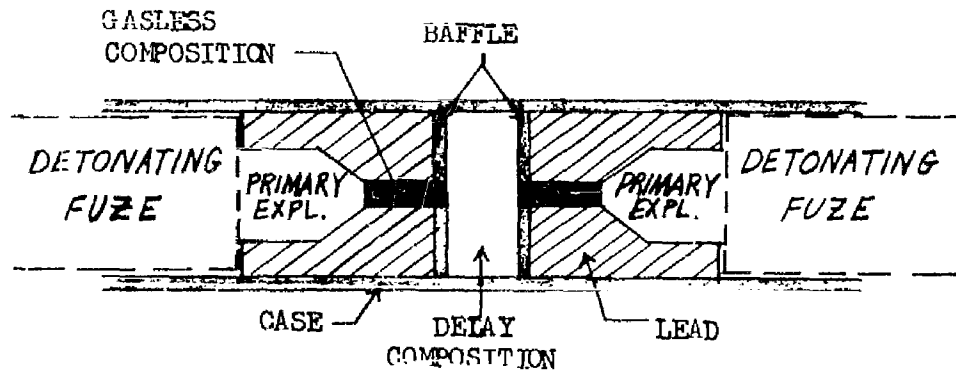


Figure 4. Typical Delay Design (Patent No. 2,707,438)

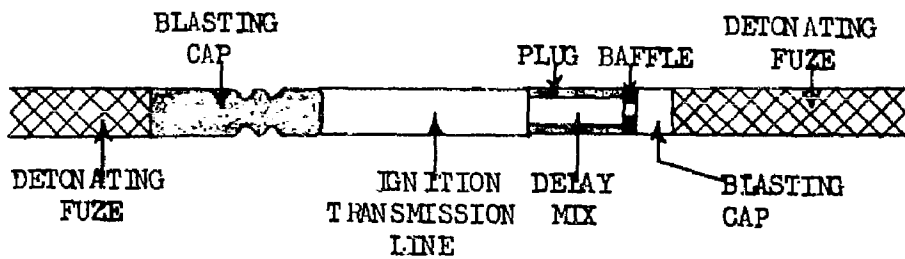


Figure 5. Delay sequence, using Ignition Transmission Line

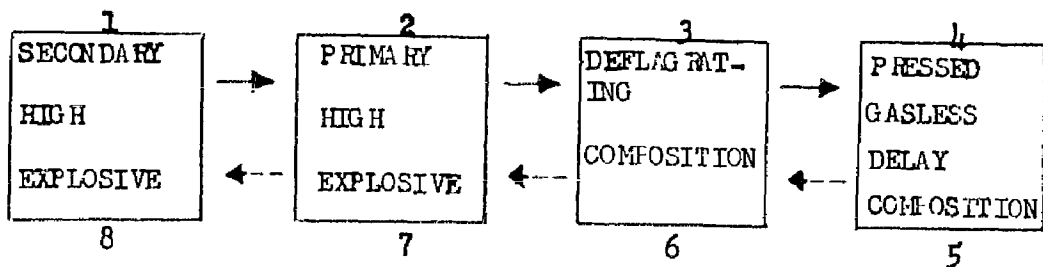


Figure 6. Series Arrangement in Blasting Delays

## TRANSITION FROM DETONATION TO DEFLAGRATION

The relative ease of the transition from a detonating explosive to a deflagrating pyrotechnic delay mixture - a transition required in powder-train delays for detonating cord systems - depends heavily upon the composition of the detonating explosive. This transition has generally been accomplished in delay blasting devices by the series arrangement, as indicated by solid arrows in Figure 6. A similar transition back to detonation generally occurs in the reverse direction, as indicated by the dashed arrows.

The sequence 1 → 8 is the basis for the design of many 2-way delays (i.e., initiated from either end) for use in detonating fuse lines. In such delays the secondary high explosive is ordinarily PETN, TNT, or RDX, while either lead azide or mercury fulminate are suitable as primary explosives.

In some cases the deflagrating composition may be omitted, although the extent of baffling between steps 2 and 4 must be adequate to prevent "blow through." Where a deflagrating composition is employed, black powder, a mixture of smokeless powder/potassium chlorate/lead sulfocyanate, or mixtures such as magnesium/barium peroxide/selenium, and bismuth/selenium/potassium chlorate, are common.

Itemization of the large number of gasless delay compositions that may be used is beyond the scope of this report.

## SEALING OF DELAY UNITS

### Shock-Pass Heat Filters

The usefulness of shock-pass heat filters (SPHF) in MDF delays becomes apparent in systems where it is desirable to have a hermetic seal between the MDF and the delay composition. It is well known<sup>12</sup> that detonation can be propagated through steel and glass plates if the plate thickness is less than a certain critical value,  $S_c$ . For thicknesses greater than  $S_c$ , detonation cannot re-form on the opposite side of a plate impacted on one side by a detonation wave in a given charge. For a thickness less than  $S_c$ , detonation will re-form on the opposite side of the plate at a point which is of variable distance away from the plate. The re-formation time,  $T$ , of the detonation can be calculated from the relation

$$T = \Delta t - S_1 / V^* = \tau_a + S_1 \left( \frac{1}{D} - \frac{1}{V^*} \right)$$

where  $\Delta t$  is the observed total elapsed time between the incident collision on one side of the plate and the re-formation of detonation in the explosive on the opposite side;

$S_1$  is a thickness less than the critical value,  $S_c$ ;

$V^*$  is the average shock velocity across the plate;

$T_a$  is the apparent time lag determined by simply extending the time-distance streak-camera trace of the incident wave and determining the displacement from it of the re-formed detonation wave along the time axis (the trace of Figure 7 is for SPHF initiation of Composition B at  $S_1/S_c \sim 0.75$ );

$D$  is the detonation velocity in the explosive used.

Although the magnitude of  $T_a$  (0.21 to 3.10  $\mu$ sec through steel and glass plates for 5.08 and 7.62 cm in diameter of Composition B, with  $S_1 \ll S_c$ ) does not place shock-pass heat filters in the category of delays, they would have separate merit as sealing devices, not only in MDF delays but also in other components initiated by MDF in the through-bulkhead fashion (as in Figure 8).

The possibility of utilizing moving pistons for sealing between MDF and the delay is good. For example, the design shown in Figure 9 employs Bridgeman's unsupported area principle to seal the MDF core volume after functioning.

## DISCUSSION

Because there has been little or no demand in the past for delays of several seconds in low energy detonating cord systems, few developmental efforts on such devices have been reported. However, detonating fuse delay devices with delay times in the range of 20 to 300 milliseconds have been developed for use in the blasting industry. Such devices, with appropriate modifications, hold promise for use as low energy detonating cord delays with delay times of several seconds.

Scaling up the delay time from milliseconds to seconds will involve modifications in the basic design. This involves not only establishing a proper delay column length, but also maintaining effective and reliable detonation-to-deflagration transition. Determining such factors as baffle size, shape, and composition is largely empirical, but design technology in this area is highly developed.

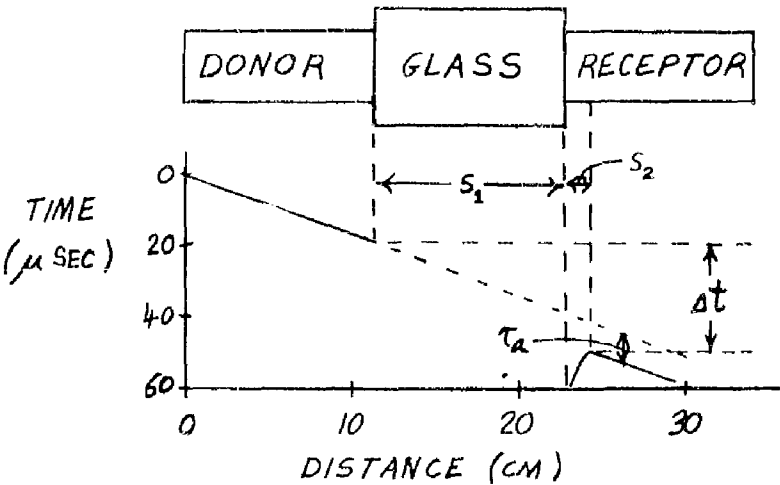


Figure 7. Time-Distance Shock-Pass Heat Filter (SPHF) Trace

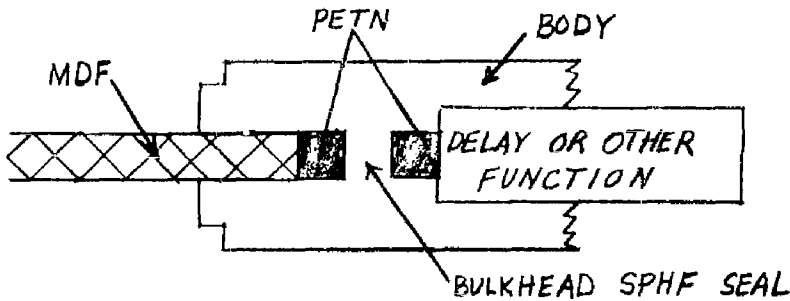


Figure 8. Example of a typical Thru-Bulkhead Ignition

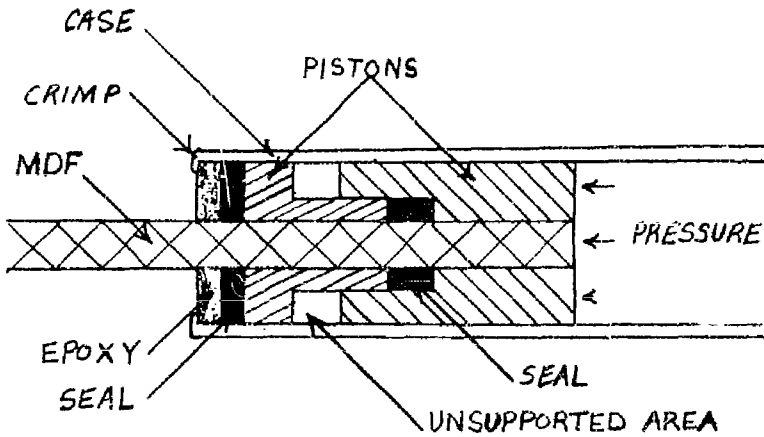


Figure 9. MDF Delay Seal

Shock-pass heat filters (SPHF) offer a convenient means for providing a complete seal between detonating cord and a delay device. Mathematical descriptions of SPHF's have been supported by a large amount of experimental data.



APPENDIX

DELAY DEVICES PATENTED

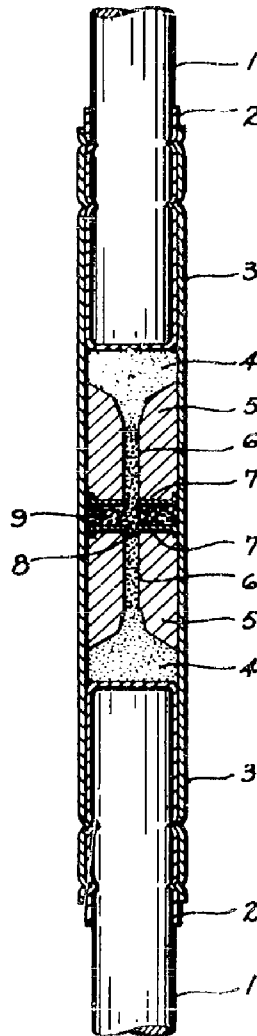
May 3, 1955

W. MANN ET AL

2,707,438

SHORT INTERVAL DELAY BLASTING DEVICE

Filed May 26, 1954



INVENTORS

WILLIAM MANN &  
GORDON TOWELL

BY *Edward J. Ransom*  
AGENT

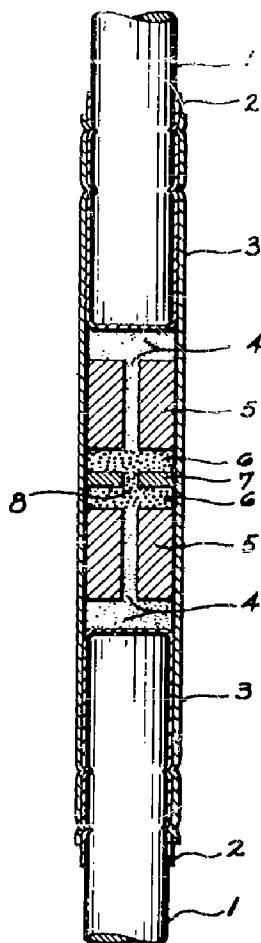
May 3, 1955

W. E. HAMILTON

2,707,439

SHORT INTERVAL DELAY BLASTING DEVICE

Filed May 26, 1954



INVENTOR.

WILLIAM E. HAMILTON

BY *Bernard J. Korman*

AGENT

Feb. 28, 1956

H. A. LEWIS ET AL  
BLASTING EXPLOSIVE DEVICE  
Filed April 17, 1951

2,736,263

FIG. 1.

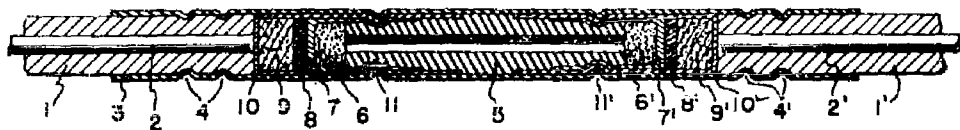


FIG. 2.

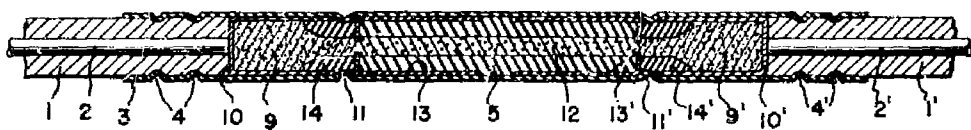


FIG. 3.

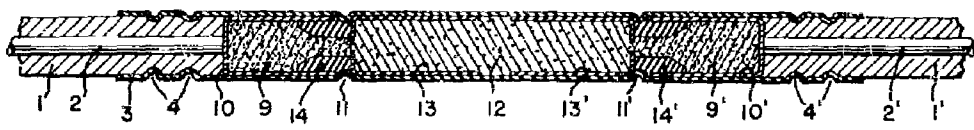


FIG. 4.

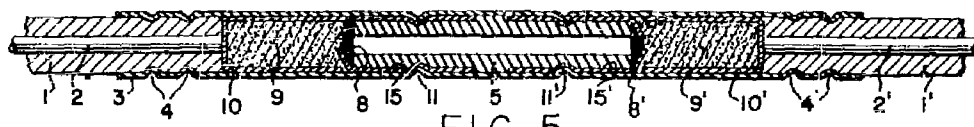


FIG. 5.

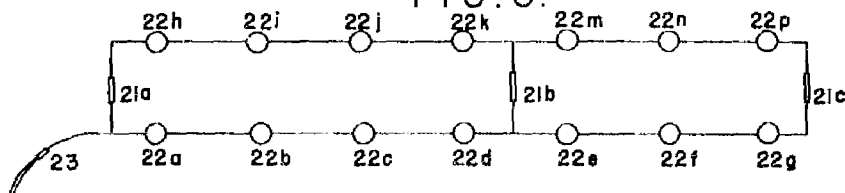
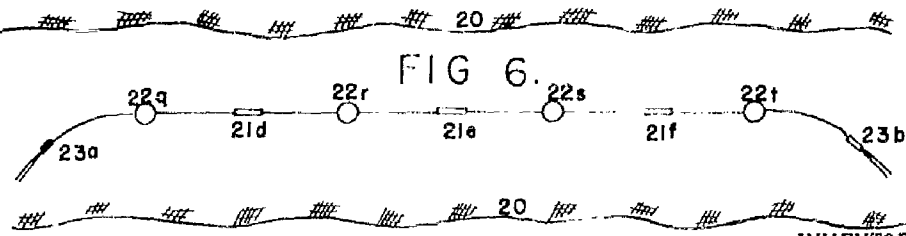


FIG. 6.



INVENTORS:  
HAROLD ARTHUR LEWIS and  
GEORGE ADELBERT NODDIN  
BY *J. A. Wilson*  
*Joseph J. Kunkel*  
ATTORNEYS.

June 25, 1957

F. H. G. McCAFFREY ET AL

2,796,834

SHORT INTERVAL DELAY ELASTING DEVICE

Filed March 9, 1956

3 Sheets-Sheet 1

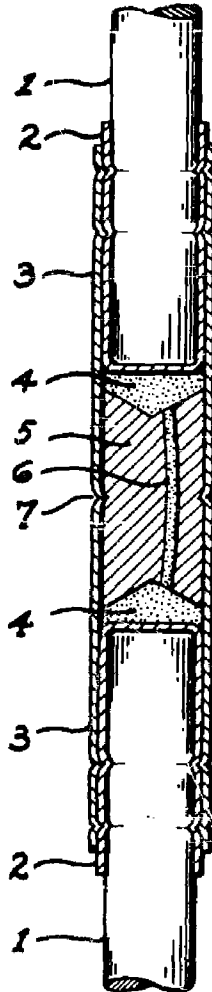


Fig. 1

INVENTORS

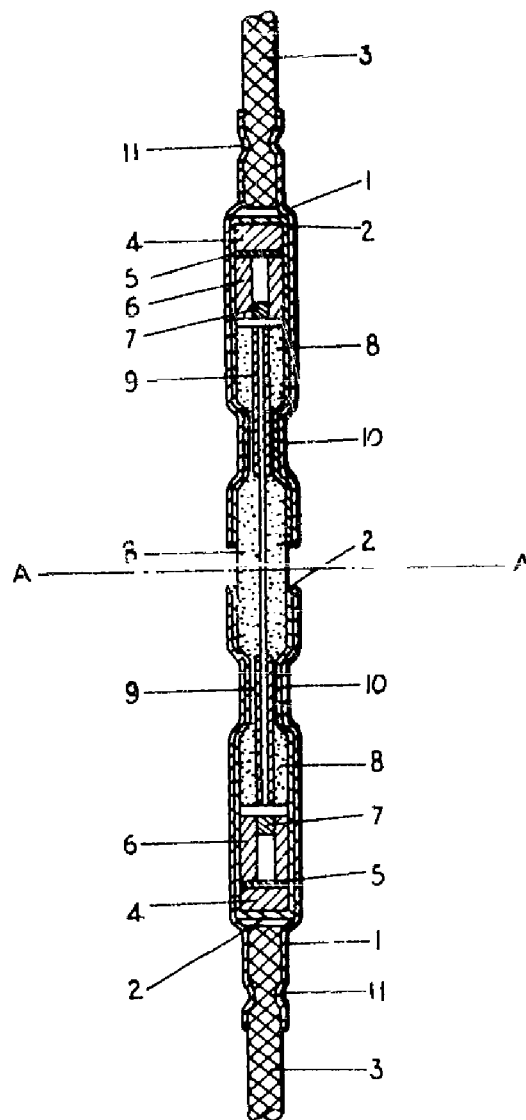
FRANCIS H. G. McCAFFREY,  
WILLIAM E. HAMILTON

BY *Bernard J. Rosen*  
AGENT

June 23, 1959

W. FORSYTH  
DELAY BLASTING DEVICES  
Filed March 15, 1956

2,891,476



INVENTOR  
William Forsyth

Cushman Darby & Cushman  
ATTORNEYS

Feb. 2, 1960

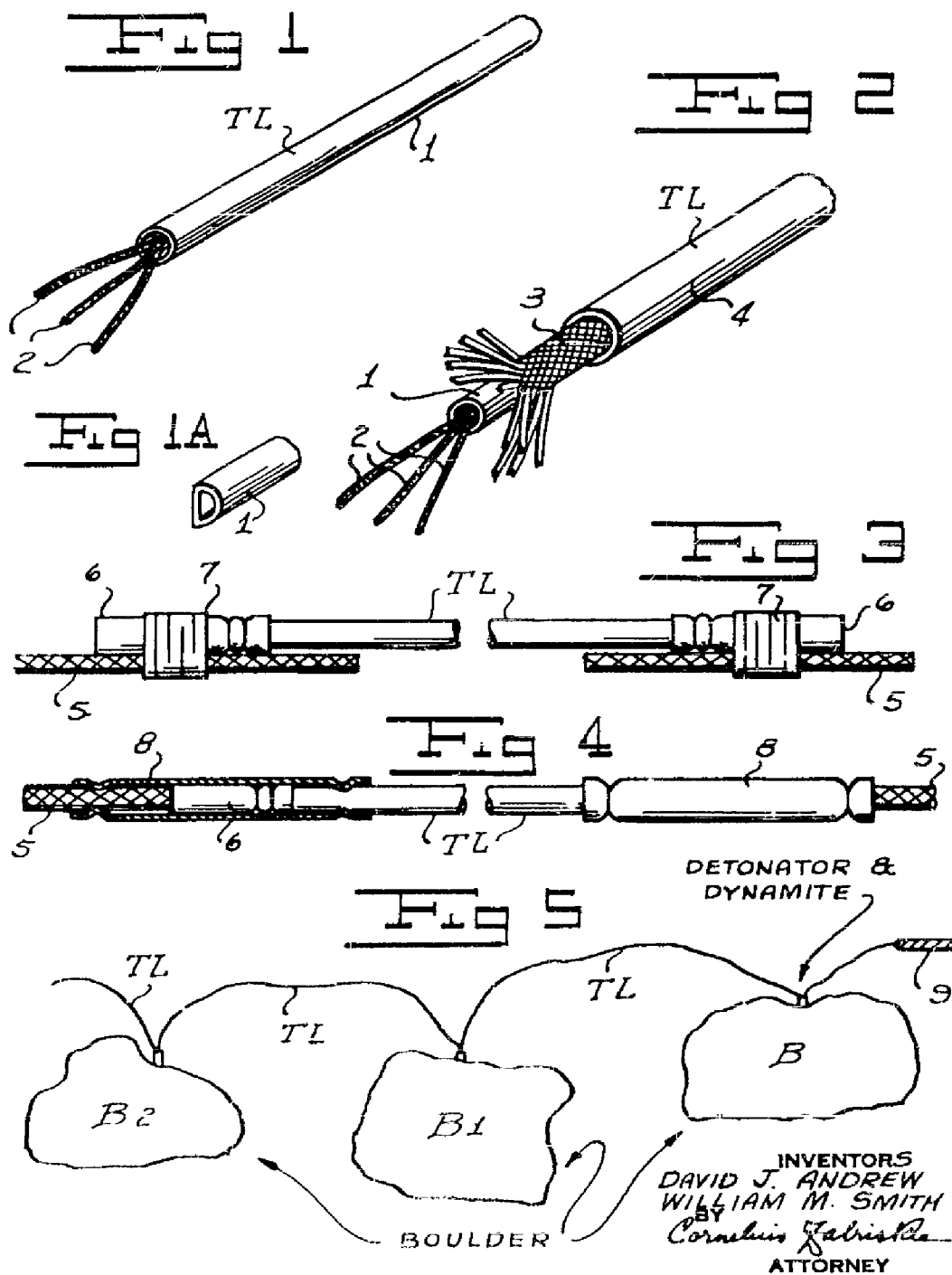
D. J. ANDREW ET AL

2,923,239

IGNITION TRANSMISSION LINE AND SYSTEMS INCLUDING THE SAME

Filed July 26, 1957

2 Sheets-Sheet 1



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#### OTHER

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AD. ACCESSION NO.  
FRANKFORD ARSENAL, Research and Development Group,  
Pitman-Dunn Institute for Research, Philadelphia, Pa.  
PROTECHNIC DELAY DEVICES FOR LOW ENERGY DETONATING CORD  
SYSTEMS by J. P. Kowalick

EA Rpt M60-26-1, Apr 64: 22 pp incl illustrations  
 OWS Code 3110.16.8500.1-1-20

A study was initiated to survey the field of pyrotechnic delay devices as they pertain to systems where relatively low energy transfer is accomplished through detonating cord having a core of small amounts of high explosive. Detonating fuse delays developed for use in the blasting industry incorporate powder trains of the sequence - high explosive to deflagrating composition, to delay composition. Although such delays appear to be in common use, their delay times do not exceed approximately 300 msec, and their reliability has not been established. Furthermore, a design problem may exist in scaling up the delay time to the order of several seconds. Functional descriptions of these delays are presented. A method is presented for providing a complete seal between detonating cord and the delay device.

References cited, although not all-inclusive, are indicative of current and past interest in this subject.

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1. Aircraft Escape Systems
2. LEDC
3. Delays

I. FA Rpt M64-26-1, Apr 64  
II. J. F. Kowalick  
III. CWS Code 4110.16.850C.1.20

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FA Rpt M64-26-1, Apr 64; 22 pp incl illustrations  
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FRANKFORD ARSENAL, Research and Development Group,  
Pittman-Dunn Institute for Research, Philadelphia, Pa.  
PYROTECHNIC DELAY DEVICES FOR LOW ENERGY DETONATING CORD

Unclassified Report  
FA Rot M64-26-1, Apr 64; 22 pp incl illustrations  
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Pittman-Dunn Institute for Research, Philadelphia, Pa.  
PYROTECNIC DELAY DEVICES FOR LOW ENERGY DETONATING CORD

Unclassified Report  
EA Rpt MGA-26-1, Apr 64; 22 pp incl illustrations  
OWS Code 4110.16.85300.1.20

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- clusive of current and past interest in this subject.

<p>AD- FRANKFORD ARSENAL, Research and Development Group, Pitman-Dunn Institute for Research, Philadelphia, Pa. PYROTECHNIC DELAY DEVICES FOR LOW ENERGY DETONATING CORD SYSTEMS by J. F. Kowalick</p> <p>FA Rpt M64-26-1, Apr 64: 22 pp incl illustrations ONS Code 4110.16.8500.1.20</p> <p>A study was initiated to survey the field of pyrotech- nic delay devices as they pertain to systems where rela- tively low energy transfer is accomplished through deto- nating cord having a core of small amounts of high explo- sive. Detonating fuse delays developed for use in the blasting industry incorporate powder trains of the sequence - high explosive to deflagrating composition, to delay composition. Although such delays appear to be in common use, their delay times do not exceed approximately 300 msec, and their reliability has not been established. Furthermore, a design problem may exist in scaling up the delay time to the order of several seconds. Func- tional descriptions of these delays are presented. A method is presented for providing a complete seal between detona- ting cord and the delay device. References cited, although not all-inclusive, are in- dicative of current and past interest in this subject.</p> <p>UNCLASSIFIED</p>	<p>AD- FRANKFORD ARSENAL, Research and Development Group, Pitman-Dunn Institute for Research, Philadelphia, Pa. PYROTECHNIC DELAY DEVICES FOR LOW ENERGY DETONATING CORD SYSTEMS by J. F. Kowalick</p> <p>FA Rpt M64-26-1, Apr 64: 22 pp incl illustrations ONS Code 4110.16.8500.1.20</p> <p>A study was initiated to survey the field of pyrotech- nic delay devices as they pertain to systems where rela- tively low energy transfer is accomplished through deto- nating cord having a core of small amounts of high explo- sive. Detonating fuse delays developed for use in the blasting industry incorporate powder trains of the sequence - high explosive to deflagrating composition, to delay composition. Although such delays appear to be in common use, their delay times do not exceed approximately 300 msec, and their reliability has not been established. Furthermore, a design problem may exist in scaling up the delay time to the order of several seconds. Func- tional descriptions of these delays are presented. A method is presented for providing a complete seal between detona- ting cord and the delay device. References cited, although not all-inclusive, are in- dicative of current and past interest in this subject.</p> <p>UNCLASSIFIED</p>	<p>UNCLASSIFIED</p> <p>1. Aircraft Escape Systems 2. LEDC 3. Delays</p> <p>I. FA Rpt M64-26-1, Apr 64: J. F. Kowalick II. ONS Code 4110.16.8500.1.20 III.</p> <p>DISTRIBUTION LIMITATIONS: None; obtain copies from DDC.</p> <p>UNCLASSIFIED</p>
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